Remnants of the Sagittarius Dwarf Spheroidal Galaxy around the young globular cluster Palomar 12

D. Martínez-Delgado

Instituto de Astrofísica de Canarias, E38200 La Laguna, Tenerife, Canary Islands, Spain

R. Carrera

Instituto de Astrofísica de Canarias, E38200 La Laguna, Tenerife, Canary Islands, Spain

C. Gallart

Instituto de Astrofísica de Canarias E38200 La Laguna, Tenerife, Canary Islands, Spain

R. Zinn

Yale University, Department of Astronomy, P.O. Box 208101, New Haven, CT 06520-8101

Received ____________________; accepted ____________________

ABSTRACT

Photometry of a large field around the young globular cluster Palomar 12 has revealed the main-sequence of a low surface-brightness stellar system. This main-sequence is indicative of a stellar population that varies significantly in metallicity and/or age, but in the mean is more metal poor than Pal 12. From the brightest part of the main-sequence, we infer a distance of 18.8 or 22.6 kpc, depending on whether we assume it corresponds to the main-sequence turnoff of an old or an intermediate-age metal poor population, respectively. In either case, the distance to this system and Pal 12 are so similar that their association is extremely likely. Since the stellar system is also detected in a field 2° North of Pal 12, it extends to a minimum of 0.9 kpc, which is consistent with the radius of a typical dwarf spheroidal (dSph) galaxy or the tidal stream from one.

We argue that the most likely interpretation is that the stellar system and Pal 12 are debris from the tidal disruption of the Sgr dSph galaxy. Previously, Dinescu et al. (2000) have shown that the orbit of Pal 12 is consistent with it having been captured from Sgr. We show that the stellar system and the central region of Sgr have similar color-magnitude diagrams. Finally, the position of Pal 12 on the sky and its distance are very close to predictions for the southern tidal stream from Sgr (Martínez-Delgado et al. 2001). We discuss briefly the implications for the evolution of Sgr and the Galactic halo.

Subject headings: Galaxy: formation — Galaxy: structure —Galaxy:halo — (Galaxy:) globular clusters: individual (Pal 12) — galaxies: individual (Sagittarius)

1. Introduction

In recent years, there has been a convergence of thinking regarding the formation of large galaxies such as the Milky Way. The picture of building the galactic halo from merging "fragments" resembling dwarf galaxies, which Searle & Zinn (1978, hereafter SZ) proposed on the basis of the properties of the Milky Way globular clusters, is regarded as the local manifestation of the hierarchical galaxy formation theory whereby dwarf galaxies were the first to form and their subsequent mergers created large galaxies (e.g. Moore et al. 1998; Navarro, Frenk & White 1995).

The Milky Way continues to be one of the best places to test this picture, and it is supported by, for example, the discovery of the Sagittarius dwarf spheroidal galaxy (Sgr dSph; Ibata, Gilmore & Irwin 1994) in the process of merging with the Galactic halo, the identification of stellar streams in the halo (Majewski 1999; Côté et al. 1993; Arnold & Gilmore 1992; Helmi et al. 1999; Ibata et al. 2001; Yanny et al. 2000; Vivas et al. 2001), and the possibility that several dwarf spheroidals (dSph) and outer globular clusters lie along two distinct streams that may be the remnants of larger parent satellite galaxies or SZ "fragments" (Lynden-Bell & Lynden-Bell 1995; Fusi Pecci et al. 1995). Recent studies have also suggested that the two of the most luminous Galactic globular clusters (M54, associated with Sagittarius, Sarajedini & Layden, 1995; and Omega Centauri, Lee et al. 1999) might be the nuclei of dSphs galaxies. Extending previous suggestions, van den Bergh (2000) has argued that the "young" globulars located in the outer halo might be the nuclei of extinct dSph galaxies and has suggested that searches for the parent galaxies may prove worthwhile. The vestiges of these parent systems may have remained undiscovered because they have very faint surface brightnesses and because most clusters have been only observed with small fields of view centered on the clusters. We report here our survey of a large field surrounding Palomar 12 (Pal 12)

Pal 12 is a remote globular cluster located at a distance of 19 kpc from the Sun. It is significantly younger than the average age of halo globular clusters (Gratton & Ortolani 1988; Stetson et al. 1989; Rosenberg et al. 1998) and is a member of the "younger halo" globular cluster group, which Zinn (1993) proposed was accreted after the collapse of the central regions of the Galaxy. On the basis of its age and radial velocity, Lin & Richer (1992) argued that Pal 12 may have been captured from the Magellanic Clouds. The measurement of its proper motion and the determination of its orbit around the Milky Way by Dinescu et al. (2000) have shown that Pal 12 was probably not captured from the Magellanic Clouds but originated instead in the Sgr dSph galaxy.

In this paper, we report the detection of a very low density stellar system in the same direction and, to within the errors, the same distance as Pal 12. The stellar population of this system is significantly different from that of Pal 12. It is consistent with the properties of a dSph galaxy, and we show that it resembles the central region of the Sgr dSph galaxy. We argue that the most likely interpretation of these data is that this system and Pal 12 are indeed more debris from the tidal disruption of the Sgr dSph galaxy by the Milky Way.

2. OBSERVATIONS AND DATA REDUCTION

Pal 12 was observed in B and R Johnson–Cousins filters with the Wide Field Camera (WFC) at the prime focus of the 2.5 m Isaac Newton Telescope (INT) at the Roque de los Muchachos Observatory on the island of La Palma (Canary Islands, Spain) in June 2001. The WFC holds four 4096×2048 pixel EEV CCDs with pixel size $0\farcs33$, which provides a total field of about $35' \times 35'$. The field was centered at $10'$ North of the center of Pal 12 with the purpose of including the extra-tidal regions around the cluster (Field 1). In addition, a field situated 2° North of the cluster's center was also taken with the purpose of gauging the field-star contamination (Field 2). However, this field is not far enough away to avoid the large stellar system that we have discovered in the environs of Pal 12. Another a control field at Northern galactic latitute, which was observed during the same run, has been used instead. Because this field and Pal 12 are situated at similar l and $\mid b \mid$, their halo-star densities are expected to be similar. Positions (columns 2 to 4) and total integration times of these fields in B (column 5) and R (column 6) are given in Table 1.

Bias and flatfield corrections were made with IRAF. DAOPHOT and ALLSTAR (Stetson 1994) were then used to obtain the instrumental photometry of the stars. About 8456 and 6236 stars were measured in both bands in Field 1 and 2 respectively. For the final photometric list, we selected stars with $\sigma < 0.20$, $-1 < SHARP < 1$ and $0 < CHI < 2$ as provide by ALLSTAR. These criteria reject extended objects, so the background contamination is expected to be only stellar-shaped objects. The atmospheric extinction and the transformations to the standard Johnson–Cousins photometric system were obtained from 52 measurements of 20 standard stars from the Landolt (1992) list. The photometric conditions during the observing run were stable and produced very small zero point errors for the photometric transformation: $\pm$ 0.020 mag in B and $\pm$ 0.016 in R. The standard errors of the extinction were always smaller than 0.01 in both filters. Aperture corrections were obtained from a larger number of isolated stars and were accurate to $\pm$ 0.01 mag in both filters. The offsets between the different WFC chips were obtained from observations of several standard fields in each chip, and then removed with a precision of better than 0.01 mag. Taking all uncertainties into account, we estimate the total zero-point errors of the photometry are $\sim$ 0.025 in both filters.

3. RESULTS

Figure 1a shows the color-magnitude diagram (CMD) for the WFC field centered in Pal 12 (Field 1). In addition to the main-sequence (MS) of the cluster, a MS-like feature is observed at bluer color, overlapping to the MS of the cluster at $B - R \sim 0.8$ and $V > 21.0$. Most importantly, this feature is also clearly seen in the CMD of the field situated $\sim 2^\circ$ North of the center of Pal 12 (Field 2), which proves that it has substantial angular extent and contains a large number of stars.

This unexpected feature of the Pal 12 diagram is more evident in Figure 1b, which shows the CMD of the extra-tidal field of Pal 12. This includes the part of Field 1 beyond the tidal radius of the cluster (i.e. for $r > 17'$) and one-half of the area of Field 2. These regions have almost indistinguishable CMDs, with the only difference that the density of stars in the MS-like feature is larger in the cluster's field (Field 1). The total area plotted in Fig. 1b is $35' \times 35'$ (see Table 1 for coordinates). For comparison, the CMD of the control field situated at (l,b)=$(28.7, 42.2)$ in the North is shown in Figure 1c. The total area of this field is the same as that plotted in Fig. 1b. The absence of the MS feature in the CMD of the control field is the most striking difference between these Northern and Southern hemisphere regions. This difference cannot be explained by a smooth halo model. The control field has slightly smaller l and $\mid b \mid$ than the fields in the direction to Pal 12. If the halo is symmetric about the galactic plane and has smooth density contours, either spherical or flattened towards the plane, the control field and not the fields in the direction to Pal 12 should contain a higher density of halo stars. This is clearly not the case (compare the regions bordered by $22 >'' V'' > 18$ & $0.6 < B - R < 2.0$ in fig. 1b and 1c). Moreover, the excess of stars in Fig. 1b over Fig. 1c occurs primarily in a narrow color $0.6 < B - R < 1.1$ and magnitude, $22 >'' V'' > 20$, range that is consistent with the main-sequence of a discrete object and not a random mixture of stars in various phases of evolution that is spread out along the line of sight.

One possibility is that these MS stars are debris from the tidal disruption of Pal 12 itself. However, a comparison between Fig 1a and Fig 1b shows that the extra-tidal stellar population is bluer than that of Pal 12 (see Sec. 4). In addition, this feature displays a significant width in color, indicating the presence of a range of age and/or metallicity and/or some depth along the line of sight, as expected of a dwarf galaxy. The stellar density of this MS is also higher than that expected in the case of tidal disruption of the cluster. The simplest explanation is that this MS feature is not due to Pal 12 but to a separate stellar population that is part of a dSph galaxy or a tidal stream from one. The presence of this feature throughout the area covered by Field 2 puts a lower limit of 0.9 kpc to the extension of the stellar system, assuming that it is at the same distance as Pal 12 (19.0 kpc; see below). This size is compatible with the width of a tidal stream crossing the field (e.g. Sgr tidal stream; Newberg et al. 2002) or the projected tidal radius of a typical dSph at the cluster's distance.[1].

Measuring the distance to this low density stellar system is crucial to determining if it is related to Pal 12. We estimate that the magnitude of the MS turnoff is "V" $= 20.37 \pm 0.10$, after correction for the small interstellar extinction ($E(B-V) = 0.037 \pm 0.002$) obtained from the reddening maps by Schlegel, Finkbeiner & Davis 1998 (SFD). However, due to the low surface brightness (LSB), only the densest part of the MS is visible in the CMD. This effect probably causes the turnoff magnitude to be measured too faint. To correct for this, we have used a CMD of the central region of Sgr that was cleaned of foreground stars(see Martínez-Delgado, Gómez-Flechoso, Aparicio & Carrera 2002, in preparation for more details) and scaled to the surface brightness that is observed in our field. We conclude that the turnoff magnitude should be corrected by -0.1 mag, which yields a value of "V" $= 20.27 \pm 0.10$, for our best estimate, which changes the distance by 10%. For a stellar population of an old dSph galaxy (stellar ages in the interval 10-15 Gyr and

[1]A typical dSph with a tidal radius of ~ 1 kpc would have angular radius of 3 degrees at this distance

$[Fe/H] \approx -1.30$), the turnoff magnitude is M_V=3.9 (see Martínez-Delgado et al. 2001) and a resulting distance modulus of $(m-M)_o = 16.37 \pm 0.15$, which corresponds to a distance $d_o = 18.8\pm$ 1.3 kpc. For a younger population (age 5-11 Gyr, matching the main body of the Sgr dSph galaxy; Layden & Sarajedini 2000), the turnoff magnitude is then $M_V = 3.5$ and the distance modulus would be $(m-M)_o = 16.77 \pm 0.15$, ($d_o = 22.6\pm$ 1.6 kpc). The distance modulus of Pal 12 is $(m-M)_o = 16.39 \pm 0.1$ (Rosenberg et al. 1998, but corrected using the interstellar reddening given in this paper), yielding $d_o = 19.0 \pm 0.9$ kpc. In either case, Pal 12 and the LSB system are in close proximity, which would be a very remarkable coincidence if they were unrelated. It is highly probable that Pal 12 is embedded in the system.

4. THE PARENT GALAXY OF PAL 12

For a decade, Pal 12 has been considered to be one of the best candidates for having been captured from another galaxy. Based on its young age with respect to other globular clusters in the galactic halo, Lin & Richer (1992) suggested this cluster may have originated in the Magellanic Clouds, which contain globular clusters of all ages. Fusi Pecci et al. (1995) supported this hypothesis because of Pal 12 is aligned with the Magellanic Stream. van den Bergh (1994) suggested the association of Pal 12 with Small Magellanic Cloud (SMC), on the basis of chemical and structural similarities with its clusters.

While one can argue that the uncertainties of the proper motion of the Pal 12 leave some space for these hypotheses (Dinescu et al. 2000), there is an additional reason to doubt the association of Pal 12 with the Magellanic Stream. Deep surveys have shown that the Stream is devoid of stars and comprised entirely of gas (Brück & Hawkins 1983; Guhathakurta, P. & Reitzel 1998; Ibata et al. 2002), and this absence of stars is consistent with at least some simulations of the merger of the Milky Way-LMC-SMC system

(Maddison, Kawata & Gibson 2002).

Dinescu et al. (2000) have shown on the basis of the orbit of Pal 12 that the Sgr dSph galaxy is much more likely to be its parent galaxy than the Magellanic Clouds. Recent surveys of Sgr (Mateo, Olszewski & Morrison 1998; Ibata et al. 2001; Majewski et al. 2000; Yanny et al. 2000; Martínez-Delgado et al. 2001; Martínez-Delgado, Gómez-Flechoso & Aparicio 2002) have provided strong observational evidence that this galaxy forms a giant stream that wraps completely around the Milky Way in an almost polar orbit, in good agreement with the predictions of theoretical models (Gómez-Flechoso, Fux & Martinet, 1999; Johnston, Sigurdsson & Hernquist 1999 ; Helmi & White 2001). The position of Pal 12 on the sky ($\sim 40^{\circ}$ from the Sgr's main body) is very close to that predicted for the Sgr Southern stream (see Martínez-Delgado et al. 2001). The predicted distance for the Sgr's tidal stream at the cluster's position is $\sim$ 19 kpc (Martínez-Delgado et al. 2002), in good agreement with the distance obtained in Sec. 3 for the LSB system. In addition, Dinescu et al. (2000) have shown that in terms of age, metallicity, luminosity, and central concentration, Pal 12 resembles the three low-mass clusters previously associated with Sgr.

The CMD of the extra-tidal field of Pal 12 is consistent with the presence of the Sgr tidal stream. Fig 2 shows a comparison between the observed CMD and a model CMD for the Sgr tidal stream, which was made using the control field plotted in Fig. 1c to represent the Milky Way's halo and a decontaminated CMD of the main body of Sgr (see Sec. 3) to represent the stream. Since the control field in Figure 1c was originally deeper than the Pal 12 field, we have added some dispersion and varied the completeness of the data in Figure 1c to match the photometric errors and completeness of the Pal 12 photometry. The magnitude and color of Sgr were shifted in -0.25 and 0.1 mag respectively to take into account the distance and interstellar reddening of Pal 12, and the surface brightness was scaled to obtain a fit with the observed CMD. The similarity between the observed and the model CMDs (see Fig. 2) is striking, and strengthens the case that the LSB system is tidal debris from the Sgr dSph galaxy.

The CMD of the LSB system also resembles those of previous detections of the Sgr Southern stream. Majewski et al. (2000) reported a MS turnoff at V=21 in a field situated at (l,b)= (11°, -40°), which is only at $\sim 20°$ from Pal 12. In the Sloan Digitized Sky Survey (SDSS), Newberg et al. (2002) found a similar structure (named S167-54-21.5) in the CMD of a long, narrow region centered on the celestial equatorial and $15° < \alpha < 0°$, that could be also part of the Sgr tidal stream.

As we noted above, the MS of the LSB system is bluer than that of Pal 12 and extends to approximately the same bright magnitude. These characteristics indicate that this population is more metal poor than Pal 12 ($[Fe/H]$=-1.0; Brown, Wallerstein & Zucker 1997) and may be as old or older than it, since lower metallicity isochrones have brighter turnoffs for a given age. From comparison with theoretical isochrones (Bertelli et al. 1994), the MS feature has intermediate color between the MS isochrones of $[Fe/H]$=-1.7 and $[Fe/H]$=-0.7, with a mean value of $[Fe/H] \sim -1.2$. This is similar to the metallicity of the metal-poor component of the main body of Sgr ($[Fe/H]$= -1.3; Layden & Sarajedini 2000), and that of the giants in the Northern tidal stream of Sgr (Dohm-Palmer et al. 2001).

5. DISCUSSION

Our detection of a LSB stellar system around Pal 12 indicates that this young globular cluster is associated with a dSph galaxy, and it strengthens considerably the contention of Dinescu et al. (2000) that Pal 12 originated in the Sgr dSph galaxy. The destruction of Sgr has therefore released at least 5 globular clusters to the Galactic halo, and it is possible that additional ones remain undetected among the globular clusters of the outer halo. Two of the Sgr clusters (M54 and Ter 8) are similar in age to the oldest globular clusters in the Milky Way. A third (Arp 2) is slightly younger than these other two (Buonanno et al. 1998; Layden & Sarajedini 2000). The much younger Sgr cluster (Ter 7) and Pal 12 (Buonanno et al. 1998; Rosenberg et al. 1998) are several Gyrs younger than the other three Sgr clusters, and they are the youngest and most metal-rich globular clusters in the galactic halo. Sgr resembles the Fornax dSph galaxy in having 5 globular clusters, although their histories of cluster formation are significantly different. Only one of the Fornax clusters is clearly younger than the other four, and this cluster (cluster 4, Buonanno et al. 1999) is both older and less metal rich than the youngest Sgr clusters (Ter 7 and Pal 12). The three "young" Sgr clusters constitute one quarter of the "young" globular clusters now in the Galactic halo (van den Bergh 2000). It seems likely that many, if not all, of the other young halo clusters, and a sizable fraction of the old clusters as well, originated in dwarf galaxies that later merged with the Milky Way. As vividly demonstrated by the huge stellar streams from Sgr, this process not only added globular clusters to the halo, but also contributed large numbers of stars of different ages and metallicities, as predicted by the SZ scenario.

Spectroscopic observations by Brown et al. (1997) have shown that Pal 12 is almost unique among halo globular clusters by having $[\alpha/Fe]$=0.0 instead of ≈ 0.3. This low ratio is a sign of metal enrichment by Type Ia supernovae (Brown et al. 1997), the progenitors of which are thought to be C+O white dwarfs in binary systems. Since the evolution of these systems is much slower than that of massive stars, a significant delay may occur between the onset of star formation in a galaxy and the detonation of Type Ia supernovae (e.g. Hillebrant & Niemeyer 2000). Pal 12 is sufficiently young with respect to the oldest stars for it to have formed after the first Type Ia supernovae. The identification of Pal 12 as a member of a dSph galaxy can explain its formation out of gas that had remained separate from the Milky Way. The measurement of the abundance ratios in several red giants in Sgr by Smecker-Hane & McWilliam (1999) have shown that two metal-poor stars

($[Fe/H] < -1$) are α enhanced while 9 others with $[Fe/H] > -1$ have $[\alpha/Fe] \sim 0.0$. The chemical composition of Pal 12 ($[Fe/H] = -1$, $[\alpha/Fe]$=0.0, Brown et al. 1997) is also consistent with membership in Sgr.

Finally, the association of Pal 12 with the Sgr stream also provides new data on position, distance and radial velocity of an unknown part of the stream, situated at $\sim 40^\circ$ South East of the main body of the galaxy. This information will be very useful to test and refine our theoretical model (Martínez-Delgado et al. 2002, in preparation), that is fundamental for the reconstruction of the dynamical history of Sgr and to constrain its total mass and dark matter content.

We are grateful to M. A. Gómez-Flechoso, for making her Sgr model available to us and for several fruitful suggestions. We also thanks to R. García-López and M. Shetrone for many useful comments. This work is based on observations made with the 2.5 m Isaac Newton Telescope operated on the island of La Palma by the Isaac Newton Group in the Spanish Observatorio del Roque de Los Muchachos of the Instituto de Astrofísica de Canarias. RZ was supported by grant AST 00-98428 from the National Science Foundation.

REFERENCES

Arnold, R., & Gilmore, G. 1992, MNRAS, 257, 225 & Rees, M. 1984, Nat, 311, 511

Bertelli, G., Bressan, A., Chiosi, C., Fagotto, F. & Nasi, E. 1994, A&AS, 106, 275

Brown, J. A., Wallerstein, G., & Zucker, D. 1997, AJ, 114, 180

Brück, M. T. & Hawkins, M. R. S. 1983, A&A, 124, 216

Buonanno, R., Corsi, C. E., Pulone, L., Fusi Pecci, F., & Bellazzini, M. 1998, A&A, 333, 505

Buonanno, R., Corsi, C. E., Castellani, M., Fusi Pecci, F., & Zinn, R. 1999, AJ, 118, 1671

Côté, P., Welch, D. L., Fischer, P., & Irwin, M. J. 1993, ApJ, 406, L59

Dinescu, D. I., Majewski, S. R., Girard, T. M. & Cudworth, K. M. 2000, AJ, 120, 1892

Dohm-Palmer, R. C., Helmi, A., Morrison, H., Mateo, M., Olszewski, E. W., Harding, P., Freeman, K. C., Norris, J. C., & Shectman, S. A. 2001, ApJ, 555, L37

Fusi Pecci, F., Bellazzini, M., Cacciari, C. & Ferraro, F. R. 1995, AJ, 110, 1664

Gómez-Flechoso, M. A., Fux, R., & Martinet, L. 1999, A&A, 347, 77

Gratton, R. G. & Ortolani, S. 1988, A&AS, 73, 137

Guhathakurta, P. & Reitzel, D. B. 1998, in ASP Conf. Ser.136, Galactic Halos, ed. D. Zaritsky (San Francisco: ASP), 22

Helmi, A., White, S. D. M., de Zeeuw, P. T., & Zhao, H. 1999, Nat, 402, 53

Helmi, A. & White, S. D. M. 2001, MNRAS, 323, 529

Hillebrandt, W. & Niemeyer, J. C. 2000, ARA&A, 38, 191

Ibata, R. A., Gilmore, G., & Irwin, M. J. 1994, Nat, 370, 194

Ibata, R. A., Lewis, G. F., Irwin, M., Totten, E., Quinn, T. 2001, ApJ,551, 294

Ibata, R. A., Lewis, G. F., Irwin, M. J. & Cambrésy, l. 2002, MNRAS, in press (astro-ph/0110691)

Johnston, K. V., Sigurdsson, S., & Hernquist 1999, MNRAS, 302, 771

Landolt, A. U. 1992, AJ, 104, 340

Layden, A. C. & Sarajedini, A. 2000, AJ, 119, 1760

Lynden-Bell, D. & Lynden-Bell, R. M. 1995, MNRAS, 275, 429

Lee, Y.-W., Joo, J.-M., Sohn, Y. -J, Rey, S. -C., Lee, H.-C., & Walker, A. R. 1999, Nature, 402, 55

Lin, D. N. C. & Richer, H. B. 1992, ApJ, 388, L57

Maddison, S. T., Kawata, D., & Gibson 2002, in *The Evolution of Galaxies II: Basic Building Blocks*, ed. M. Sauvage et al., Kluwer, in press (astro-ph/0201401)

Majewski, S. R. 1999, in *The Third Mt. Stromlo Symposium*, eds. B. K. Gibson, T.S. Axelrod, & M. E. Putman, (San Francisco: ASP), 76

Majewski, S. R., Ostheimer, J. C., Patterson, R. J., William, W. E., Johnston, K. V., & Geisler, D. 2000, AJ, 119, 760

Martínez-Delgado, D., Aparicio, A., Gómez-Flechoso, M. A. & Carrera, R. 2001, ApJ, 549, L199

Martínez-Delgado, D., Gómez-Flechoso, M. A. & Aparicio, A. 2002, in *Observed HR diagrams and stellar evolution: the interplay between observational constraints and theory*, ed. J. Fernandes and T. Lejeune, ASP conference series, in press (astro-ph/0110703)

Mateo, M., Olszewski, E. W., & Morrison, H. L. 1998, ApJ, 508,L55

Moore, B., Governato, F., Quinn, T., Stadel, J., Lake, G. 1998, ApJ, 499, L5

Navarro, J., Frenk, C. & White, S. D. M. 1995, MNRAS, 275, 720

Newberg et al. 2002, ApJ, in press (astro-ph/0111095)

Rosenberg, A., Saviane, I., Piotto, G. & Held, E. V. 1998,A&A, 339, 61

Sarajedini, A. & Layden, A. 1995, AJ, 109, 1086

Searle, L., & Zinn, R. 1978, ApJ, 225, 357 (SZ)

Schlegel, D., Finkbeiner, D. & Davis, M. 1998, ApJ, 500, 525

Smecker-Hane, T. & McWilliam, A. 1999, in ASP Conf. Ser. 192, Spectrophotometric Dating of Stars and Galaxies, ed. I. Hubeny, S. R. Heap, & R. H. Cornett (San Francisco: ASP), 150

Stetson, P. B. 1994, PASP, 106, 250

Stetson, P. B., VandenBerg, D. A., Bolte, M., Hesser, J. E. & Smith, G. H. 1989, AJ, 97, 1360

van den Bergh, S. 1994, AJ, 108, 2145

van den Bergh, S. 2000, ApJ, 530, 777

Vivas, A. K., et al. 2001, ApJ, 554, L33

Yanny, B. et al. 2000, ApJ, 540, 825

Zinn, R. 1993, in ASP Conf. Ser. 48, The Globular Cluster-Galaxy Connection, ed. G. H. Smith & J. P. Brodie (San Francisco: ASP), 38

This manuscript was prepared with the AAS LaTeX macros v4.0.

Figure 1. *panel a)* Color-magnitude diagram for the WFC field centered on Pal 12 (Field 1). The narrow main-sequence (MS) of the cluster is clearly delineated. Notice that it is surrounded by a sparser and wider MS-like feature at bluer color; *panel b)* displays the CMD for an extra-tidal field of $35' \times 35'$, half of which is from Field 1 but outside of the cluster's tidal radius ($r > 17'$) and the other half is from Field 2, situated $\sim 2^{\circ}$ North of Pal 12. The MS-like feature is clearly observed at $B - R \sim 0.8$ and $21 < V < 23$; *panel c)* shows the CMD of our control field, which is the same size as the field shown in Fig 1b (see Sec 3).

Fig. 2. Comparison of the CMD of the extra-tidal field of Pal 12 (panel a; same as Fig. 1b) and a model CMD for the Sgr tidal stream (panel b), for which we used our control field to represent the Milky Way and a CMD of the main body of the Sgr dSph galaxy to represent the stellar population of the stream (see Sec. 4).

Table 1. Target Fields

Field	R.A.(J2000.0)	Dec	l	b	t_B(s)	t_R(s)
Field 1	$21^h46^m38\overset{s}{.}9$	$-21°25'00''$	30.3	-47.7	3600	1800
Field 2	$21^h49^m21\overset{s}{.}7$	$-19°20'10''$	33.5	-47.7	3900	3600
Control	$16^h11^m04\overset{s}{.}0$	$+14°57'29''$	28.7	42.2	9200	9000